OIPE JC105
DEC 2 2 2003
PATENT & TRADEMARK OFFICE

Docket No.: P2001,0263

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, Alexandria, VA 22313 20231.

By:______________________ Date: December 18, 2003

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applic. No.	:	10/685,062
Applicant	:	Henry Bernhardt et al.
Filed	:	October 14, 2003
Art Unit	:	to be assigned
Examiner	:	to be assigned
Docket No.	:	P2001,0263
Customer No.:		24131

CLAIM FOR PRIORITY

Mail Stop: Missing Parts
Hon. Commissioner for Patents,
Alexandria, VA 22313-1450
Sir:

Claim is hereby made for a right of priority under Title 35, U.S. Code, Section 119, based upon the European Patent Application 01 1091 64.2 filed April 12, 2001.

A certified copy of the above-mentioned foreign patent application is being submitted herewith.

Respectfully submitted,

____
GREGORY L. MAYBACK
REG. NO. 40,716

Date: December 18, 2003

Lerner and Greenberg, P.A.
Post Office Box 2480
Hollywood, FL 33022-2480
Tel: (954) 925-1100
Fax: (954) 925-1101

/mjb

Europäisches Patentamt	European Patent Office	Office eur péen des brevets

Bescheinigung | Certificate | Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.	The attached documents are exact copies of the European patent application described on the following page, as originally filed.	Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

01109164.2

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

EUROPÄISCHES PATENTAMT DEN HAAG · EUROPEAN PATENT OFFICE THE HAGUE · OFFICE EUROPÉEN DES BREVETS LA HAYE
237

C. v.d. Aa-Jansen

MüNCHEN, DEN
MUNICH, 30/09/03
MUNICH, LE

EPA/EPO/OEB Form 2540 - 02.91

Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 01109164.2
Demande n°:

Anmeldetag:
Date of filing: 12/04/01
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):

Infineon Technologies SC300 GmbH & Co. KG
01099 Dresden
GERMANY
ASML Netherlands B.V.
5503 LA Veldhoven
NETHERLANDS

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:

Heating system and method for heating an atmospheric reactor

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:

H01L21/00, C30B31/18, C23C16/46

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

Part of the rights were transferred from the original applicant Infineon Technologies SC300 GmbH & CO. K, Dresden,Deutschland to the above-mentioned co-applicant on 12.06.02.

Description

Heating System and Method for Heating an Atmospheric Reactor

The present invention relates to a heating system and a method for heating an atmospheric reactor.

During the manufacture of integrated circuits such as memory products substrates, especially semiconductor wafers, are processed in high-temperature ovens, called reactors, in order to deposit layers of isolating, semiconducting or conducting material. These reactors can be suited for the processing of a plurality of wafers at one time. The wafers are placed on a wafer support inside the reactor. The deposition reactor and, thus, the wafers are heated to a desired temperature. Typically, reactant gases are passed over the heated wafer, causing the chemical vapor deposition of a thin layer of the reactant material on the wafer. Alternatively, reactant gases passing over the heated wafer will immediately react with the substrate material, as is the case in thermal oxidation.

Figure 1 shows an exemplary deposition reactor which is suited for low pressure chemical vapour deposition processes. A large number of wafers (typically at least 100) is carried by a wafer carrier, for example a slotted quartz boat, so that the gas flowing direction, which is defined by the line connecting gas inlet and gas outlet and which is parallel to the longitudinal axis of the reactor, is orthogonal to the wafer surfaces. Heating means are provided in order to heat the reactor to a predetermined temperature. As soon as the predetermined temperature is reached, the reactant gases are introduced into the deposition reactor in order to effect the deposition reaction. According to the prior art method, the temperature of the deposition reactor is maintained constant during deposition.

In order to deposit silicon dioxide, for example TEOS, ($Si(OC_2H_5)_4$) is reacted at a temperature of 700°C and a pressure of 40 Pa. Silicon nitride layers can be generated by reacting SiH_2Cl_2 and NH_3 at a temperature of 750°C and a pressure of 30 Pa.

As is generally known, the deposition rate depends on the deposition temperature and the pressure inside the deposition reactor. More specifically, a higher deposition temperature results in a higher deposition rate. Accordingly, usually a temperature gradient is applied in a direction parallel to the gas flowing direction in order to compensate for the depletion of the reactant gases in that direction. As a consequence, the temperature at the reactant gases outlet is higher than the temperature at the reactant gases inlet. By these measures, it is possible to deposit a homogenous layer thickness onto all wafers which are simultaneously processed.

However, it is not possible to achieve a sufficient in plane uniformity of the layer thickness. More specifically, the layers on the wafers close to the gas outlet tend to assume a bowl shape in which the layer thickness at the edge of the wafer is greater than the layer thickness in the middle of the wafer. Typically, the difference between layer thickness at the edge and layer thickness in the middle is approximately 10 nm at a mean value of the layer thickness of 200 nm. On the other side, the layers on the wafer close to the gas inlet tend to assume a pillow shape in which the layer thickness at the edge of the wafer is smaller than the layer thickness in the middle of the wafer.

It is an object of the present invention to provide a heating system and a method for heating an atmospheric reactor by which the in plane uniformity of the deposited or oxidized layer thickness is improved.

According to the present invention, the above object is achieved by a heating system for heating an atmospheric reactor in which a plurality of wafers is held perpendicularly to the reactant gas flowing direction which is parallel to the longitudinal axis of the reactor, so as to enable a deposition process or an oxidation process, wherein said heating system is adapted to change the reactor temperature during the process.

Moreover, the above object is achieved by a method for heating an atmospheric reactor in which a plurality of wafers is held perpendicularly to the reactant gas flowing direction which is parallel to the longitudinal axis of the reactor, so as to enable a deposition reaction or an oxidation reaction, wherein the reactor temperature is changed during the process.

As the inventors of the present invention found out, the in plane uniformity of the deposited layers can be largely improved by changing the reactor temperature during the deposition process. Accordingly, the reactor temperature is no longer held at a constant value but it is changed. For example, the temperature can be lowered, raised or changed in an arbitrary manner. Examplary temperature profiles which are applied in all the zones of the reactor are illustrated in Figures 2 and 3. As is shown in Figure 2, the temperature is ramped down by 40 K, whereas in Figure 3, during deposition which starts at point A end ends at point B, the temperature is first ramped up by 60 K and then again ramped down by 60 K. The time is depicted in abitrary units (a.u.). It is to be noted that depostion and oxidation are exchangeable in this invention. A feature of the invention which is described for a deposition reaction can equally be used for an oxidation reaction.

According to a preferred embodiment, the deposition (or oxidation) reactor is divided into a plurality (usually five) of

zones along the reactant gas flowing direction. The heating system is divided into heating elements and each of the heating elements is seperately controlled so as to provide a different temperature profile indicating the temperature of the specific temperature element versus time as is shown schematically in Figure 4. The number of heating elements can be the same as the number of zones. As can be seen from Figure 4, in zone 1, which is close to the gas outlet, the temperature is ramped down from 790°C to 710°C, in zone 2 the temperature is ramped down from 770°C to 730°C, in zone 3 the temperature is maintained constant at 750°C, and in zone 4, which is close to the gas inlet, the temperature is ramped up from 720°C to 780°C.

Generally stated, the temperature is ramped down in the two thirds of the reactor which are closer to the gas outlet. It is preferred that the difference between deposition starting temperature and deposition end temperature is greater in a zone closer to the gas outlet than in a zone closer to the gas inlet. Moreover, the temperature is ramped up in the third of the reactor which is closest to the gas inlet. In the zone forming the boundary between these regions, the temperature is maintained constant during deposition.

By these measures, it is possible to adjust the optimum deposition temperature in accordance with the deposition conditions which vary in dependence from the location of the specific reactor zone. In particular, the reactant gases are depleted along the reactant gas flowing direction. Moreover, in a zone closer to the gas outlet the reactant gases are as well depleted in a direction parallel to the wafer surface so that the reactant gases are most depleted in the middle of the wafers. In the zones close to the gas inlet, in particular, in the zones located in the lower third of the reactor, this effect is less important since in these zones the effect of the depletion of the reactant gases along the reactant gas flowing direction is not so strong.

Another relevant parameter is the heat flow in a direction of the wafer surface. Generally, heat is supplied by means of a heating spiral or heating lamp which is situated at the reactor walls. Accordingly, a certain temperature of the zone of the deposition reactor refers to the temperature at the wafer edge. In addition, in most commonly used deposition reactors, at a position closest to the gas inlet, redundant heating elements are provided at a position where no wafer is placed. Accordingly, in the zone closest to the gas inlet, the heating is not only effected from the wafer edge but also from the middle of the wafer. Therefore, dependent from the specific location of the zone, different heating conditions will prevail.

More specifically, in the zones which are not closest to the gas inlet, the temperature at the wafer edge is different from the temperature in the middle of the wafer. Accordingly, by lowering the temperature of the reactor, a uniform heating amount can be achieved along the wafer surface.

On the other hand, in the zone closest to the gas inlet, the heating is not only effected from the edge as explained above. As a consequence, by raising the temperature of the reactor during the deposition, a uniform heating amount can be achieved along the wafer surface.

The effects of the present invention can be further improved if the temperature profiles of the zones are properly set so that the temperature profiles of neighbouring zones do not cross each other during the deposition process. Stated more concretely, the elevation of the temperature of one zone should be avoided, if at the same time the temperature of a neighbouring zone is lowered in order to minimize a detrimental heat flow between the zones.

The detrimental heat flow can be best suppressed if the deposition process ends at the same temperature in all zones.

Since different deposition reactors require different heating conditions, a calibration can be performed, as soon as a new batch of wafers has been processed. To this end, after the end of the deposition, the wafers of each zone are evaluated, for example using an ellipsometer. Thereafter, on the basis of the measurement results obtained, the heating conditions for the zones of the reactor are set for the next deposition processes. If the deposited layer has assumed a bowl shape, the difference between deposition start temperature and deposition end temperature must be increased in that specific zone. On the contrary, if the deposited layer assumes a pillow shape, the difference between deposition start temperature and deposition end temperature must be decreased in that specific zone.

In order to deposit the same layer thickness onto the wafers in all the zones, it is preferred that the mean value of the temperature taken over time in each of the zones is decreasing from the zone closest to the gas outlet to the zone closest to the gas inlet. For example, zone 1 assumes a mean temperature of 800°C, zone 2 assumes a mean temperature of 790°C, zone 3 assumes a mean temperature of 780°C, zone 4 assumes a mean temperature of 770°C, and zone 5 assumes a mean temperature of 760°C. This is preferred when the temperature is equally changed in all the zones, for example, lowered by a certain amount, raised by a certain amount or changed in an arbitrary manner, or when the temperature profile of every zone is changed in a different manner.

In summary, the present invention provides the following advantages:

- The in plane uniformity of the deposited layers is largely improved. In particular, a difference between the layer

thickness at the edge and the layer thickness in the middle of the wafer amounts to 4 nm at most if the mean value of the layer thickness amounts to 200 nm.

- The present invention can easily be implemented to existing deposition reactors.

- As is generally known, by raising the pressure inside the deposition reactor, the deposition rate can be raised. However, a high pressure will also result in very inhomogenous layers. By additionally regulating the temperature in accordance with the present invention, the homogenity of the layers will be improved. Accordingly, when the present invention is applied to a deposition process which is performed at an elevated pressure, the deposition rate is raised and, simultaneously, the quality of the layers in terms of their homogenity is maintained.

- The present invention can be applied to all low pressure chemical vapour deposition processes. It is particularly applicable to the deposition of silicon nitride, silicon dioxide (TEOS process and thermal oxidation), arsene oxide (TEAS process) and polysilicon layers. The advantageous effects of the present invention become especially apparent at a layer thickness of at least 30 nm. If the layer thickness is smaller, the advantages become less apparent.

The present invention will be explained in more detail with reference to the accompanying drawings in conjunction with deposition, although the invention also includes oxidation processes.

Figure 1 illustrates a CVD reactor which can be used for implementing the present invention;

Figures 2, 3 and 4 show examplary temperature profiles applied to the deposition reactor; and

Figure 5 shows the measurement results representing the uniformity of layers deposited in accordance with the examples and the comparative example.

In Figure 1, reference numeral 1 denotes a deposition reactor in which the low pressure chemical vapour deposition takes place and which is implemented as a batch furnace. Reference numeral 2 denotes gas inlet for feeding one or more reactant gases to the deposition reactor, and reference numeral 3 denotes a gas outlet for exhausting the reactant gases. As is obvious, the reactant gas flowing direction is parallel to the longitudinal axis of the reactor. Reference numeral 4 denotes a wafer carrier for carrying a plurality (usually between 100 and 150) of wafers, and reference numeral 5 denotes a heating system for heating the deposition reactor.

The reactor may be divided into 5 zones, zone 1 to zone 5, wherein zone 1 is the zone closest to the gas outlet, whereas zone 5 is the zone closest to the gas inlet. In Figure 1, reference numeral 6 denotes zone 1 and reference numeral 7 denotes zone 5.

In the present examples, a pad nitride layer is to be deposited onto silicon wafers. After that, trenches for defining storage capacitors for DRAM cells are to be etched into these wafers.

After introducing the wafers into the deposition reactor, the reactor is evacuated, and the temperature thereof is raised. Usually, the reactor is held at a standby temperature of approximately 650°C so that the temperature is to be increased by about 100 to 250°C depending on the chosen reaction conditions. As soon as a desired vacuum degree is reached, a first reactant gas is fed into the reactor. In the present case, NH_3 at a flow rate of 480 sccm (standard cubic centimeters per second) is fed into the reactor. As soon as the desired

deposition temperature is reached, a second reactant gas, which is SiH_2Cl_2 at a flow rate of 120 sccm, is fed into the reactor so that the deposition reaction will start. A typical pressure inside the deposition reactor amounts to 14,63 Pa (110 mTorr).

The temperatures at which the deposition starts and the temperature profiles during deposition are varied in accordance with the following examples and the comparative example. Since the temperature profiles are selected so that the mean temperature amounts to 800°C in zone 1, 790°C in zone 2, 780°C in zone 3, 770°C in zone 4, and 760°C in zone 5, the deposition rate amounts to 2 nm/min.

The layers are deposited at a mean value of the thickness of 200 nm within a time period of 100 minutes.

Example 1

The reactor is brought to a temperature of 820°C in zone 1, 810°C in zone 2, 800°C in zone 3, 790°C in zone 4, and 780°C in zone 5. During deposition, the reactor temperature is ramped down by 40 K in all the zones.

Example 2

The reactor is brought to a temperature of 840°C in zone 1, 830°C in zone 2, 820°C in zone 3, 810°C in zone 4, and 800°C in zone 5. During deposition, the reactor temperature is ramped down by 80 K in all the zones.

Example 3

The reactor is brought to a temperature of 840°C in zone 1, 830°C in zone 2, 820°C in zone 3, a temperature of 790°C in zone 4 and a temperature of 760°C in zone 5. During deposition, the temperature is ramped down by 80 K in zones 1 to 3,

the temperature is ramped down by 40 K in zone 4, and it is held constant in zone 5.

Example 4

The reactor is brought to a temperature of 840°C in zone 1, 830°C in zone 2, 810°C in zone 3, 790°C in zone 4 and 750°C in zone 5. During deposition, the temperature is ramped down by 80 K in zones 1 and 2, the temperature is ramped down by 60 K in zone 3, the temperature is ramped down by 40 K in zone 4, and the temperature is ramped up by 20 K in zone 5.

Example 5

The reactor is brought to a temperature of 840°C in zone 1, 830°C in zone 2, 820°C in zone 3, 785°C in zone 4 and 740°C in zone 5. During deposition, the temperature is ramped down by 80 K in zones 1 to 3, the temperature is ramped down by 30 K in zone 4, and the temperature is ramped up by 40 K in zone 5.

Example 6

The reactor is brought to a temperature of 841°C in zone 1, 832°C in zone 2, 820°C in zone 3, 790°C in zone 4 and 734°C in zone 5. During deposition, the temperature is ramped down by 82 K in zone 1, the temperature is ramped down by 84 K in zone 2, the temperature is ramped down by 80 K in zone 3, the temperature is ramped down by 40 K in zone 4, and the temperature is ramped up by 52 K in zone 5.

Comparative example

The reactor is brought to a temperature of 800°C in zone 1, 790°C in zone 2, 780°C in zone 3, 770°C in zone 4, and 760°C in zone 5. During deposition, the temperature is held constant in all zones.

When the deposition reaction is finished, the flow of the reactant gases is interrupted and the reactor is rinsed with an inert gas such as nitrogen.

Thereafter the quality of the deposited layers is evaluated as follows. The standard deviation from the mean value of the layer thickness based on 13 measurement points on the wafer surface is determined for each of the examples and the comparative example, and the results represented by uniformity sigma % are given in the following table:

Example	zone 1 [%]	zone 2 [%]	zone 3 [%]	zone 4 [%]	zone 5 [%]
1	1,14	0,92	0,77	0,37	1,07
2	0,45	0,61	0,54	0,41	1,78
3	0,49	0,59	0,22	0,17	0,95
4	0,64	0,74	0,67	0,31	0,85
5	0,58	0,73	0,47	0,32	0,69
6	0,71	0,73	0,57	0,29	0,66
comparative	1,78	1,38	1,19	1,03	0,69

The measurement results for examples 1, 2, 5 and the comparative example are illustrated in Figure 5.

As can be seen from the table, all of the examples provide a layer thickness having an improved in plane uniformity in zones 1 to 4, whereas only examples 5 and 6 provide an improved uniformity in zone 5.

However, since in normally used deposition reactors the positions of the wafer carrier of zone 5 closest to the gas inlet and the positions of the wafer carrier of zone 1 closest to the gas outlet are occupied by dummy wafers which are not used for chip production, the deteriorated in plane uniformity in zone 5 is of minor relevance for the chip production.

In summary, the present invention provides improved results in examples 1 to 4 and excellent results in examples 5 and 6.

List of Reference Numerals

1 deposition reactor
2 gas inlet
3 gas outlet
4 wafer carrier
5 heating system
6 first zone
7 fifth zone

Claims

1. A heating system (5) for heating an atmospheric reactor (1) in which a plurality of wafers is held perpendicularly to the reactant gas flowing direction which is parallel to the longitudinal axis of the reactor (1), so as to enable a deposition process or an oxidation process,
c h a r a c t e r i z e d i n t h a t
said heating system (5) is adapted to change the reactor temperature during the deposition process.

2. The heating system (5) according to claim 1,
c h a r a c t e r i z e d i n t h a t
it comprises a plurality of heating elements corresponding to a plurality of reactor zones into which the reactor (1) is divided in a direction parallel to the reactant gas flowing direction, wherein the heating element of each zone is adapted to provide a different temperature profile indicating the temperature of this specific zone versus time.

3. The heating system (5) according to claim 2,
c h a r a c t e r i z e d i n t h a t
the heating element of the zone (7) closest to the gas inlet (2) for feeding one or more reactant gases to the reactor (1) is adapted to provide a temperature profile in which the temperature is rising during the process, whereas the heating elements of the zones close to the gas outlet (3) for exhausting the reactant gases from the reactor (1) are adapted to provide temperature profiles in which the temperature is falling during the process.

4. The heating system (5) according to claim 3,
c h a r a c t e r i z e d i n t h a t
the heating elements of the zones close to the gas outlet (3) are adapted to provide temperature profiles in which the difference between the process starting temperature and process

end temperature is greater in a zone closer to the gas outlet than in a zone closer to the gas inlet.

5. The heating system (5) according to any of claims 2 to 4, c h a r a c t e r i z e d i n t h a t the heating elements are adapted to provide temperature profiles such that the temperature profiles of neighbouring zones do not cross each other during the process.

6. The heating system (5) according to claim 5, c h a r a c t e r i z e d i n t h a t the heating elements are adapted to provide the same end temperature of the process.

7. A method for heating an atmospheric reactor (1) in which a plurality of wafers is held perpendicularly to the reactant gas flowing direction which is parallel to the longitudinal axis of the reactor, so as to enable a deposition process or an oxidation process, c h a r a c t e r i z e d i n t h a t the reactor temperature is changed during the process.

8. The method for heating a reactor (1) according to claim 7, c h a r a c t e r i z e d i n t h a t each of a plurality of reactor zones, into which the reactor is divided in a direction parallel to the reactant gas flowing direction, is heated at a different temperature profile indicating the temperature of this specific zone versus time.

9. The method for heating a reactor (1) according to claim 8, c h a r a c t e r i z e d i n t h a t in the temperature profile of the zone (7) closest to the gas inlet (2) for feeding one or more reactant gases to the reactor (1), the temperature is rising during the process, whereas in the temperature profiles of the zones close to the gas outlet (3) for exhausting the reactant gases from the reactor (1), the temperature in falling during the process.

10. The method for heating a reactor (1) according to claim 9,
c h a r a c t e r i z e d   i n   t h a t
in the temperature profiles of the zones close to the gas outlet (3) the difference between the process end temperature and the process starting temperature is greater in a zone closer to the gas outlet than in a zone closer to the gas inlet.

11. The method for heating a reactor according to any of claims 8 to 10,
c h a r a c t e r i z e d   i n   t h a t
the temperature profiles are such that the temperature profiles of neighbouring zones do not cross each other during the process.

12. The method for heating a reactor according to claim 11,
c h a r a c t e r i z e d   i n   t h a t
the temperature profiles are such that the end temperature of the process is the same in each zone.

Abstract

Heating System and Method for Heating an Atmospheric Reactor

The present invention relates to a heating system and a method for heating a deposition reactor or an oxidation reactor which is particularly suited for low pressure chemical vapour deposition or oxidation.

The present invention provides a heating system for heating the reactor in which a plurality of wafers is held perpendicularly to the reactant gas flowing direction which is parallel to the longitudinal axis of the reactor, so as to enable a deposition or oxidation reaction, wherein said heating system is adapted to change the reactor temperature during the process. Further the invention provides a method for heating a reactor in which a plurality of wafers is held perpendicularly to the reactant gas flowing direction, so as to enable a reaction, wherein the reactor temperature is changed during the process. Prefereably, each of a plurality of reactor zones, into which the reactor is divided in a direction parallel to the reactant gas flowing direction, is heated at a different temperature profile indicating the temperature of this specific zone versus time. Thereby, the in plane uniformity of deposited or oxidized layers can be largely improved.

Figure 4

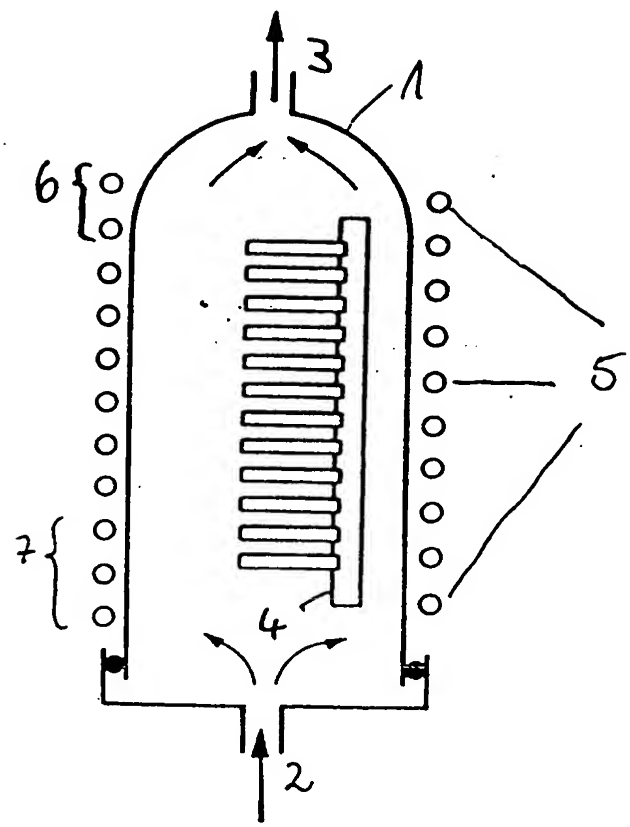


FIG. 1

FIG.2

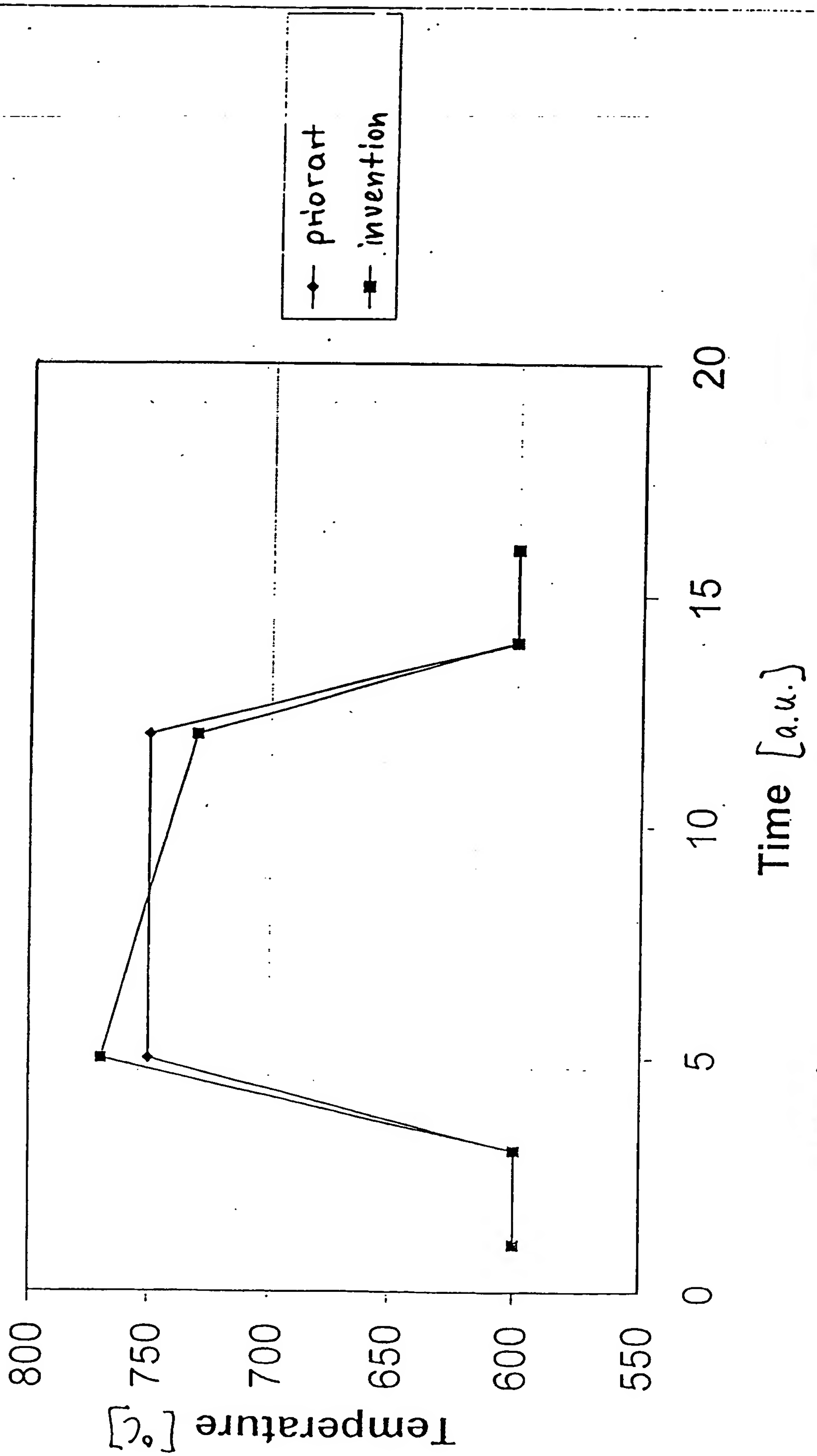

prior art
invention
800
750
700
650
600
550
Temperature [°C]
0
5
10
15
20
Time [a.u.]

FIG 2

FIG.3

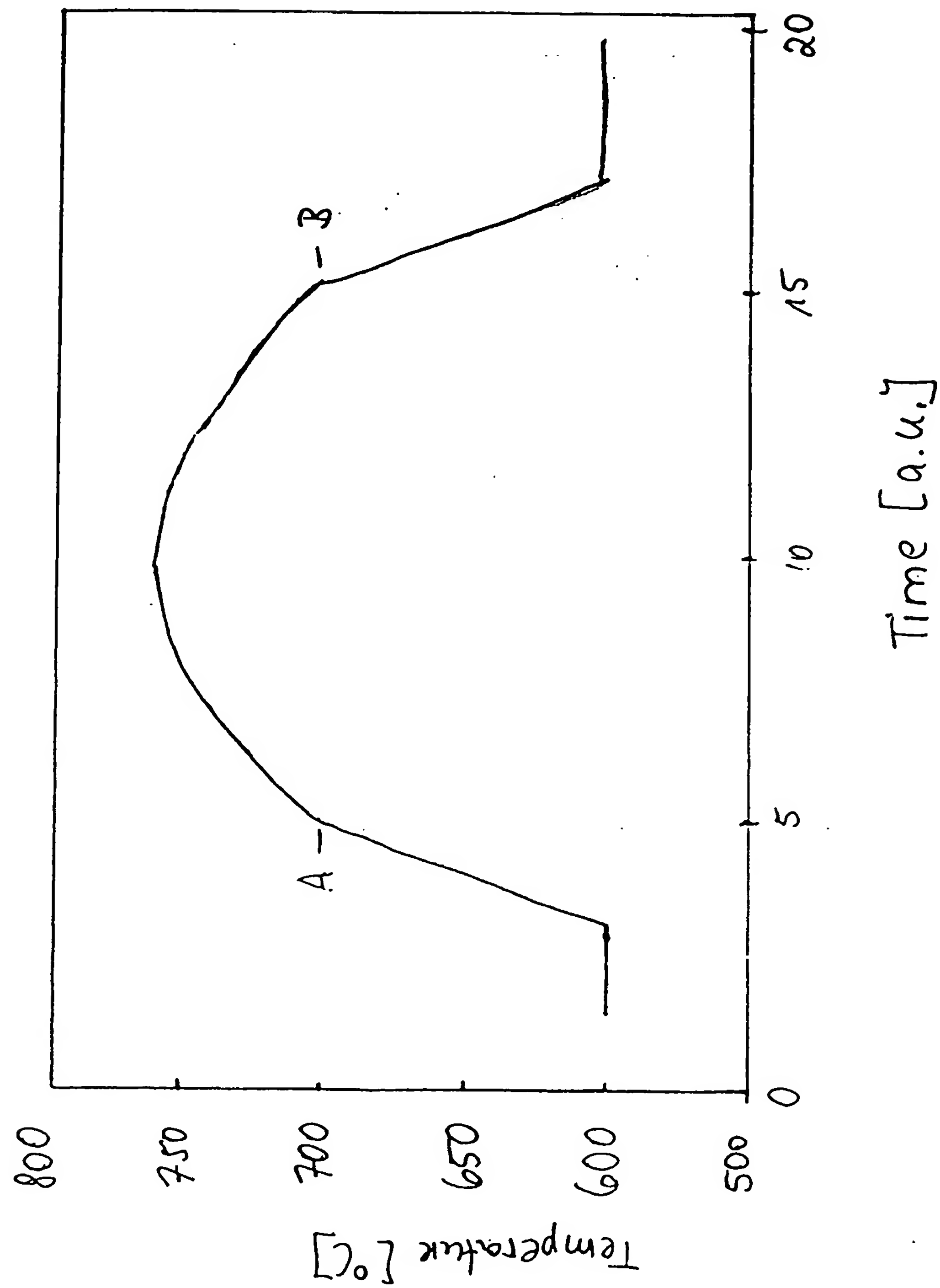
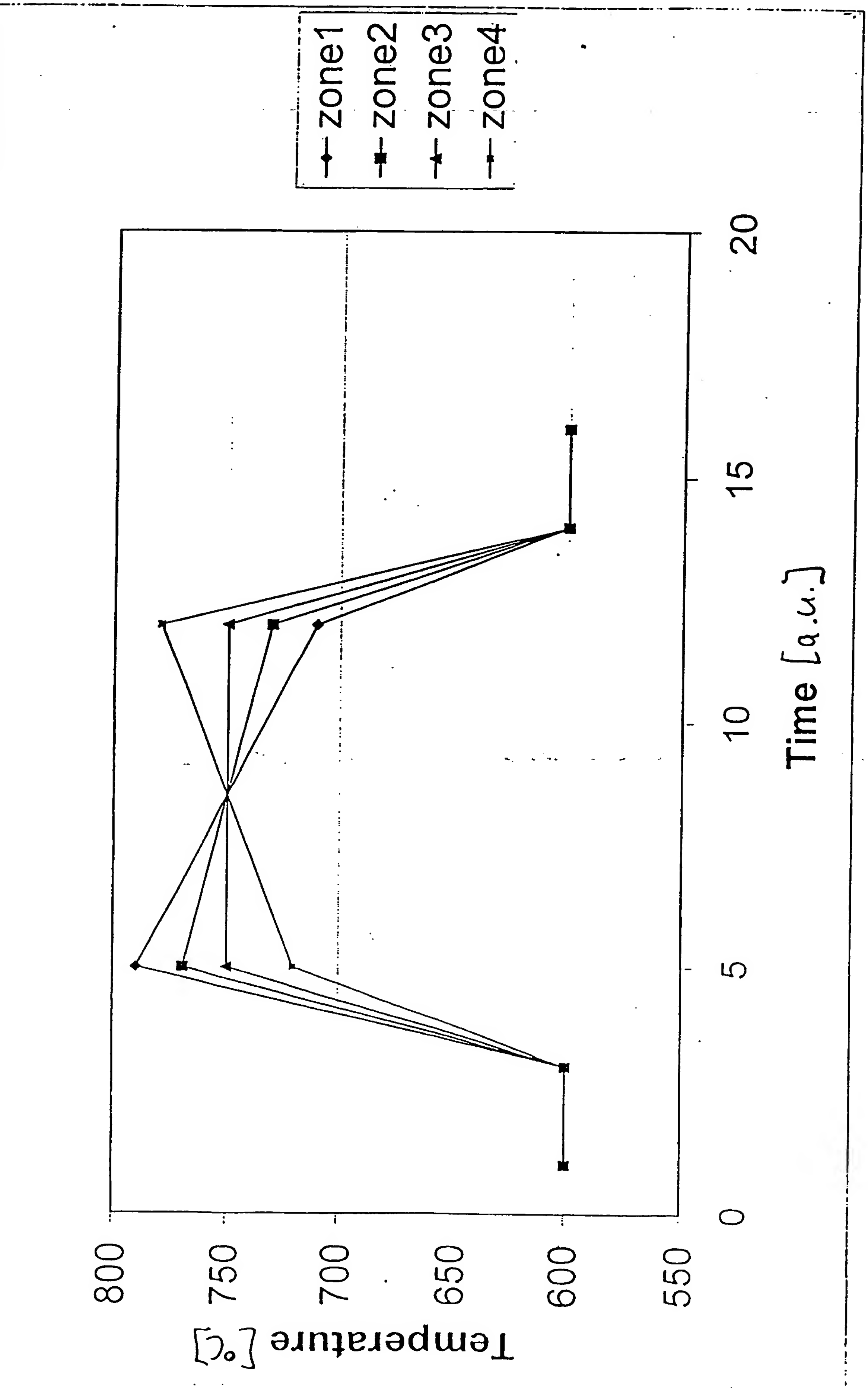


FIG. 4


zone1
zone2
zone3
zone4
Temperature [°C]
800
750
700
650
600
550
0
5
10
15
20
Time [a.u.]

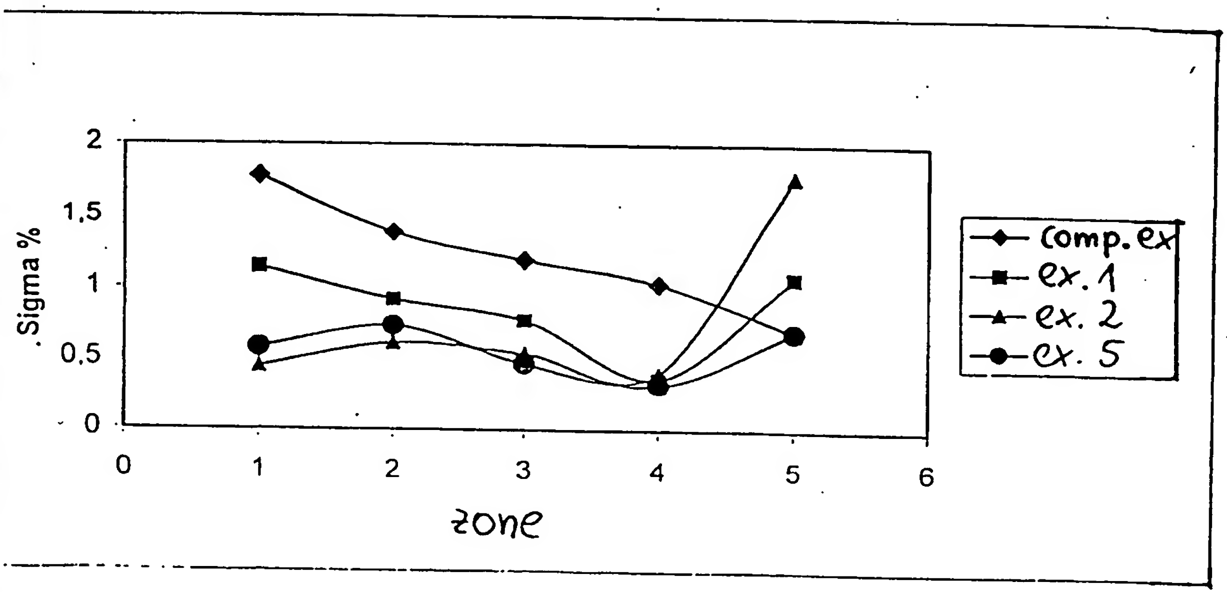


FIG 5